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Distribution, survivability and susceptibility status of *Anopheles* mosquitoes in Kamamaung Township, Kayin State in Myanmar

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ABSTRACT

Malaria endemicity is remaining in hard to reach and insurgent areas in Myanmar, where high density of primary and secondary vectors are available. Present study was determined the distribution, survivability and insecticides susceptibility status of vectors and non-vectors of malaria in Katinehtit village Kamamaung Township, Kayin State from July 2020 to June 2021. Mosquitoes were collected by Kanda net for animal bait and CDC light traps for indoor and outdoor collection from 18:00 to 00:06 hour. Survivability rate of *An. dirus*, *An. minimu*, *An. aconitus*, *An. philippinensis*, *An. vagus* and *An. culicifacies* were measured under the group of banana plants and susceptibility of collected mosquitoes were tested with WHO recommended insecteds. A total of 2207 mosquitoes consist of 13 *Anopheles* mosquito adult were collected by different collection methods by Cattle bate 1581(71.64%), Light trap indoor 174(7.88%), Light trap outdoor 297(13.46%), Morning Resting 43(1.95%) and Near the resting plant 112(5.07). Main vector *An. dirus* and *An. minimus* were mostly collected in Rainey season in high density and *An. dirus* was disappeared in hot season. Main vector *An. minimus* and secondary vector as *An. philippinensis*, *An. culicifacies*, *An. maculatus*, *An. aconitus* and nan vector *An. barbirostris* and *An. hyrcanus* were collected in all seasons. *An. philippinensis*, *An. barbirostris* and *An. hyrcanus* were abundantly collected. The highest survivability rate was found *An. dirus* and *An. vagus* for 8 days (10%) followed by *An. culicifacies* (20%), *An. philippinensis* (10%), *An. minimus* (20%) for 7 days and lowest was found *An. aconitus* for 6 days (20%). High density of *An. dirus* larvae were collected from rock pools and *An. minimus* was collected in sand pools, rice fields water, bed of Yonsalin creeks and water pools. All the collected mosquitoes were susceptible to Deltamethrin 0.05%, Permethrin 0.75% and Cyfuthris 0.15%. In conclusion, high density of main malaria vectors and secondary vectors were collected from Katinehtit village is a high risk area of malaria. Although all the collected main and secondary vectors were susceptible to WHO recommended insecticides. Therefore, Long Lasting Insecticide impregnated nets can be preventing the transmission of malaria in this area.

Keywords: Susceptibility; Survivability; Vector; *An. dirus*; *An.minimus*; Density; Anopheles; Deltamethrin; Kanda net; Larval habitats.

1. Introduction

In Myanmar, the malaria burden remains high despite a significant reduction of cases during the last decade, in the context of the disease elimination by 2030. Now the malaria is reduced in most parts of the areas, morbidity and mortality of malaria is reducing from 4% to 0.0001% by 100000 populations 2011 to 2018 despite, malaria remains in remote and border areas [1]. The Ministry of Health has planned the elimination of the diseases by 2030 [2]. In the last decade in the Greater Mekong Sub-region, a continued decline of malaria cases (by 74%) and deaths (by 94%), although malaria remained as a major public health problem in a big population of people particularly in hard to reach areas or remote areas and along the international borders [3,4,5]. Malaria is the seriously illness and deadly vector-borne disease worldwide in tropical and subtropical climate zone with an estimated that 228 million cases, and 405,000 deaths in 2018, the high risk was mostly in the African Region (93%) and followed by the South-East Asia Region (3.4%) including Myanmar [6]. Myanmar is a border line area with India, China, Bangladesh and Thailand. The study areas are situated not far away from the border area of Thailand. As per the World Malaria Report 2018, in 2017, 80% of the global malaria burden was borne by 15 countries in sub-Saharan Africa and India. India (with 4% malaria cases) is one of the five countries that contributed 50% malaria cases worldwide. The other four countries are Nigeria (25%), Democratic Republic of the Congo (11%), Mozambique (5%), and Uganda (4%) [7]. Malaria is transmitted by vectors of *Anopheles* mosquitoes which are differ in different country. In Myanmar malaria is highly transmitted by *Anopheles dirus* and *An. minimus* which *Anopheles* mosquitoes have its own

biology and distribution, previously, *An. dirus* are mostly found in deep forested areas and plain areas as well as their larvae are found in rock pools and water pools in Rakhaine, Bago, Taninthayi Yoma mountain range and Kayin State. Previously *An. minimus* larvae are found in forest fence and slowly running water now the larvae are found in rice field water, water pools, sand pools in different areas and domestic water well in Ye Township, Mon State [8,9,10,11] and *An. dirus* larvae are abundantly collected in domestic water well in Kayin, Mon and Taninthayi region of Myanmar [12,13,14]. And secondary vectors or suspected vector such *as An. annularis, An. maculatus, An. culicifacies, An. sinunsis, An. aconitus, An. kochi* and *An. philippinensis* are abundantly collected in Rakhine, Bago Yoma mountain range, Mandalay Regions, Mon and Kayin State [8,9], *Anopheles annularis, An. maculatus, An. culicifacies, An. aconitus,* and *An. kochi* were found aporozoite positive in salivary gland by ELISA test [12, 15, 16, 17]. Two studies are in strong contrast with the mosquito collection in Cambodia which found malaria parasites in only three mosquito species: *A. dirus* s.s., *A. minimus* s.s. and *An. barbirostris* s.s [18]. However, it should be noted that only human landing catches were used by Durnez et al., [18], whereas all the infected mosquitoes collected in St. Laurent et al., [19] were captured by cow baited tents and 75.2% of infective samples in this study were collected in Cow bait big mosquito nets, further highlighting the importance of opportunistic feeding behaviour in SEA mosquitoes [20]. In the neighboring countries are Thailand, China, India and Bangladesh, in Thailand *An. dirus, An. minimus, An. maculatus* and *An. philippinensis* are main vector of malaria [21,22]. In China main malaria vectors are *An. dirus, An. minimus, An. anthropophagus* and *An. sinensis* [23]. In India and Bangladesh *An. dirus, An.minimus, An.sundiagus, An stephensi* and *An. culicifacies* are main vector of malaria [7]. The present study aim to study the distribution, survivability and insecticides susceptibility of *Anopheles* adult mosquito in natural condition in Kamamaung Township Kayin State.

1.1. Study objectives

(i) To determine the distribution of *Anopheles* mosquitoes and larva habitats in Katinehtit village in Kamamaung Township. (ii) To access the susceptibility status of *Anophees* mosquitoes against WHO recommend insecticides. (iii) To measure the survivability rate of collected *Anopheles* mosquitoes under banana Plants in field area.

2. Materials and methods

2.1. Study areas

The study was conducted in Katinehtit village Kamamaung Township, Kayin State to know the distribution, survivability and insecticides susceptibility status of *Anopheles* mosquitoes.

2.2. Study periods

Year round study was done from July 2020 to June 2021.

2.3. About Katinehtit village

Katinehtit village is consisted in Kamamaung Township. It is a plain area and surrounded by hills and mountains. And Yunsalin creek is running East to West of the village. Mostly paddy fields are lied around the village. Rice plants are growing in raining season. About 2500 villagers live in village, most of the villagers are farmer, wood cutters and some are hunter, some are working as government staffs and some are school teachers. In the rainy and

cold seasons all areas are swamps and water pools around the village. Rice plants are growing well in this paddy fields. All the households have 2 to 12 cows and 1-7 goats in farms and all the households have 5 to 15 chickens. Different kinds of small plants such as flower plants (rose, poinsettia (Ywat Hla), Jasmine (Sabe), fruit plant (as mangoes, guavea (Marlaca), papaya, banana, and bean plants), and bamboo and other trees are growing well around the village. One police station, one RHC and one high school and one abbey, one pagoda and three monasteries are available in the village.

2.4. Mosquitoes collection

Mosquitoes were collected by using Kanda net (K-net) 330x330x220 inch as animal bait and indoor and outdoor mosquitoes were collected by CDC light traps method. Outdoor CDC light traps were hung near the houses and roof of the house from 18:00 hours to 6:00 hour. Ten sets of CDC light traps were used to collected the mosquitoes near the houses for 5 days. After 5 days all the CDC light traps were removed to another 10 houses for five days catching. Next day morning, all the traps were collected from catching stations. Monthly indoor morning resting mosquitoes were collected using sucking tube by 4 mosquito collectors from 5 to 7 am. [24] (WHO 1975) in randomly selected 10 houses in the village.

2.5. Survivability test

Survivability test of collected *An. dirus. An. minimus, An. aconitus, An. philippinensis, An. vagus* and *An. culicifacies* were tested in natural condition in study areas according to WHO [24]. Cattle bait catch blood fed *Anopheles* were tested for the measurement of survivability under the banana plants in large paper cups according to WHO. 10% sugar water was soaked with cotton wool and provided on paper cups as food. These cotton wools were removed daily with new one and moisture was maintained with water soaked small cotton towels. After one day, and 50ml of water with filter paper lined 100ml beaker was placed in paper cup for oviposition [24]. Daily survivability rate of *Anopheles* mosquitoes, Temperature and Humidity were measured and recorded in the morning.

2.5.1. Procedure

10 each of blood fed female *Anopheles* mosquitoes *as, An. dirus, An, minimus, An. aconitus, An. philippinensis, An. vagus,* and *An. culicifacies* were put in to large paper cup and freshly prepared 10% sugar solution was supplemented individual paper cup as food. Species name, putting time, placing time were marked on the cups surface by permanent marker pen individually according to the species. The cups were hung under the banana plants in natural condition (Temp 28±2 °C, RH 88±5). After one day of test, filter paper lined 100ml beaker with 50ml of water was placed in paper cup for oviposition. Mortality and survivability rate were measured at every morning at 7:00 am. All the cups were protected from natural enemy as ants. Survivability rate was measured and recorded daily till the survivability rate was 0%. Survivability rate was calculated in percentage.

2.6. Larval surveys

Larval surveys for identification of breeding sites were conducted in and around three kilo-meters radius from the study site in the village. Larval were collected from water pools, domestic wells, stream, creeks, sand pools and all different types of water holding places as water pockets, coconut shells, discarded tins and utensils bamboo stumps

including foot print of animals by 3 Dips/water holding place [24].The captured larvae and pupae were put in labeled plastic bags and brought back to the laboratory for species identification and colonization.

2.7. Mosquito species identification

Collected *Anopheles* mosquitoes and adult emerged from larval survey were identified according to different identification keys [25,26,27].

2.8. Data analysis

Monthly collected mosquito data, survivability, and susceptibility status were analyzed by using Microsoft Excel software. Mosquito density, survivability rate of *Anopheles* mosquitoes was calculated in percent.

3. Results

Table 1 shows that a total of 2207 Anopheline mosquitoes consist of 13 species were collected. Of these primary vectors *An. dirus* 93(4.21%), and *An. minimus* 243(11.01%), secondary vectors *An. maculatus* 125(5.66%), *An. culicifacies* 297(13.46%), *An. philippinensis* 348(15.77%), *An. aconitus* 82(3.72%), *An. annularis* 65(2.95%), *An. varuna* 53(2.40%), *An. jamesi* 56(2.54%) and *An. hyrcanus* 342(15.50%) and non-vectors *An. vagus* 114(5.17%), *An. tessellatus* 68(3.08%) and *An. barbirostris* 321(14.54%) were collected. The high density of *An. philippinensis* (15.77%), *An. hyrcanus* (15.50%) and *An. barbirostris* (14.54%) were collected followed by secondary vector *An. culicifacies* (13.46%) and main vector *An. minimus* (11.01%) and lowest density was observed *An. varuna* (2.40%) and *An. jamesi* (2.54%). In different catching methods, the highest density of *Anopheles* was collected from Animal bate big mosquito collection (71.64%) followed by outdoor light trap collection (13.46%) and lowest density was observed (1.95%) by morning resting method.

Table 1. Collection of *Anopheles* mosquitoes by different collection methods

Sr. No.	Species	Cattle bate	Light trap indoor	Light trap outdoor	Morning resting	Near resting plant	Total	Density (%)
1	*An. dirus*	46	23	17	1	6	93	4.21
2	*An. minimus*	163	38	21	6	15	243	11.01
3	*An. maculatus*	92	11	16	1	5	125	5.66
4	*An. culicifacies*	195	26	41	16	19	297	13.46
5	*An. philippinensis*	232	38	49	2	27	348	15.77
6	*An. aconitus*	56	6	16	0	4	82	3.72
7	*An. annularis*	48	3	9	0	5	65	2.95
8	*An. vagus*	62	6	23	12	11	114	5.17
9	*An. varuna*	37	4	11	0	1	53	2.40

10	*An. jamesi*	42	3	7	2	2	56	2.54
11	*An. tessellatus*	53	3	12	0	0	68	3.08
12	*An. barbirostris*	267	7	37	2	8	321	14.54
13	*An. hyrcanus*	288	6	38	1	9	342	15.50
	Total collected	1581	174	297	43	112	2207	100.00
		71.64	7.88	13.46	1.95	5.07	100.00	

Table 2 shows that breeding sources of *Anopheles* larvae in Katinehtit village and found that a total of 8 kinds of *Anopheles* mosquitoes breading sources were recorded. Water pools, rock pools, sand pools, Rice fields, Ponds, slowing running water, water bed of Yunsalin creek and foot prints were found plenty of *Anopheles* mosquito larvae found. Of this the highest density of *Anopheles* mosquitoes were collected from rice fields 32.06% followed by sand pools 24.49% and lowest density of *Anopheles* mosquitoes were collected from slowing running water. Main vector *An. dirus* and *An. minimus* larvae were collected from Rock pools and also *An. minimus* larvae were collected from water pools, Sand pools, slowly running water and bed of Younsalin creek with secondary vector *An. maculatus, An. aconitus, An. culicifacies* and *An. philippinensis* and other non-vector of *Anopheles* larvae.

Table 2. Collection of *Anopheles* larvae from different breeding sources (Larval Habitats) in Katinehtit village

Sr. No.	**Larval habitats**	**Total inspected habitats**	**Total positive habitats**	**Species of larvae**	**Total larvae**	**Habitat wise total larvae**	**Density (%)**
1	Water pools	23	20	*An. maculatus*	34	162	5.07
				An. minimus	26		
				An. philippinensis	41		
				An. aconitus	15		
				An. barbirotris	46		
2	Rock pools	8	4	*An. dirus*	17	47	4.00
				An.	23		

				minimus			
				An. aconitus	7		
3	Sand pools	16	13	*An. minimus*	54	288	24.49
				An. culicifacies	102		
				An. vagus	56		
				An. philippinensis	76		
4	Rice fields	25	23	*An. maculatus*	36	377	32.06
				An. barbirostris	67		
				An. hyrcanus	53		
				An. vagus	36		
				An. philippinensis	98		
				An.culicifacies	61		
				An. aconitus	23		
				An. jamesi	3		
5	Ponds	4	2	*An. vagus*	15	76	6.46
				An. barbirostris	24		

				An. hyrcanus	17		
6	Slowlyunning water	4	3	*An. minimus*	2	30	2.55
				An. maculatus	12		0.00
				An.aconitus	6		0.00
7	Bed of Younsalin creek	12	10	*An. maculatus*	24	134	11.39
				An. minimus	31		0.00
				An. culicifacies	28		0.00
				An. philippinensis	22		0.00
				An. barbirostris	29		0.00
8	Foot prints	20	12	*An. vagus*	69	92	7.82
				An. barbirostris	23		0.00
		112	87		1186	1186	100.00
	Positivity		77.68%				

Table 3 shows that survivability rate of *An. dirus*, *An. minimus*, *An. aconitus*, *An. philippinensis*, *An. vagus* and *An. culicifacies* under the banana plants were found different survivability rate. *An. dirus*, *An. minimus*, *An. aconitus*, *An. vagus* and *An. culicifacies* were found 100% survivability for 4 days and *An. philippinensis* was found 3 days. Longest survivability rate of *An. dirus* and *An. vagus* were found (10%) survivability for 8 days. *An. minimus*, *An.* vagus and *An. culicifacies* were found 20% and *An. philippinensis* was found (10%) survivability for 7days and *An. aconitus* was found (20%) survivability for 6 days.

Table 3. Survivability rate of different *Anopheles* mosquitoes under banana plant groups in Katinehtit village

Days	**% survivability of *Anopheles* mosquito species under the banana plants groups**											
	An. dirus		***An. minimus***		***An. aconitus***		***An. philippinensis***		***An. vagus***		***An. culicifacies***	
	Total	%	Total	%	Total	%	Total	%	Total	%	Total	
Day 1	10	100	10	100	10	100	10	100	10	100	10	100
Day 2	10	100	10	100	10	100	10	100	10	100	10	100
Day 3	10	100	10	100	10	100	10	100	10	100	10	100
Day 4	10	100	10	100	10	100	8	80	10	100	10	100
Day 5	9	90	8	80	6	60	5	50	9	90	9	90
Day 6	5	50	5	50	2	20	2	20	5	50	4	40
Day 7	3	30	2	20	0	0	1	10	2	20	2	20
Day 8	1	10	0	0			0	0	1	10	0	0
Day 9	0	0							0			

Table 4 shows that susceptibility status of collected *Anopheles* mosquitoes against WHO impregnated insecticides and found that all collected *Anopheles* mosquitoes from Katinehtit village were susceptible to Deltamethrin 0.05%, Permethrin 0.75% and Cyfuthrin 0.15% insecticides. Although *An. barbirostris* and *An. hyrcanus* was found 30-40 minutes tolerated to Deltamethrin 0.05%.

Table 4. Susceptibility status of collected *Anopheles* mosquitoes with WHO recommended insecticides

Species	**No. of tested mosquitoes**	**Insecticides**	**Susceptibility**	**Remarks**
An. dirus	30	Deltamethrin 0.05% Permethrin 0.75% Cyfuthrin 0.15%	“”	
An. minimus	30		“”	
An. maculatus	30		“”	
An. culicifacies	30		“”	
An. philippinensis	30		“”	
An. aconitus	30		“”	
An. annularis	30		“”	
An. vagus	30		“”	

An. varuna	30		“”	
An. jamesi	30		“”	
An. tessellatus	30		“”	
An. barbirostris	30		“”	30-40 min tolerated
An. hyrcanus	30		“”	30-40 min tolerated

4. Discussion

Malaria is endemic in Myanmar, mostly in border areas and insurgent areas, large parts of Myanmar becomes free from malaria. Katinehtit village is situated in Kamamaung Township Kayin State which area is a malaria endemic area. Present study determined the distribution of malaria vectors, breeding habitats, survivability and insecticides susceptibility status of *Anopheles* mosquitoes. Study revealed that higher number of malaria vector *An. minimus* was collected than *An. dirus* by cattle bait catching method. Highest density of non-malaria vector *An. barbirostris* and *An. hyrcanus* were collected followed by secondary vectors *An. philippinensis, An. culicifacies* and lowest number of *An. annularis, An. maculatus An. varuna,* and *An. jamesi* were collected. Other researchers observed that main vectors *An. dirus* and *An. minimus* and secondary vector *An. culicifacies* were abundantly collected from Thabwewa village in Bago Yoma range in Oktwin Township Bago Region and Ye Phyu Township Taninthayi Region [9,14]. A previous study of Maung Maung Mya and his party reported that highest density of *An. dirus* and *An. minimus* were collected from Kamamaung Township Kayin State and they were sibling species D and A and high density of secondary vector *An. culicifacies* B were collected in same area [28]. High density of *An. minimus* were collected from Ye Township Mon State [29]. A study in Indonesia *An. barbirostris* was found vector of malaria, although in Myanmar they are non-vector of malaria [30,8]. *Anopheles gambiae* s.l. and *Anopheles funestus* Giles are main vector of malaria and abundantly found in Jaribuni and Mtepeni in Kilifi, along the Kenyan Coast which an area of perennial malaria transmission on the coast of Kenya [31]. Moderate number of potential vectors *An. dirus* and *An. minimus* were collected from Nanyin village in Bunmouk Township Sagaing Region, Shwe Kyin Towhship Bago Region and Beelin Township Mon State and Tha-Ma-Nya Village, Hpa-an Township, Kayin State in Myanmar [32,33,34]. In Rakhine State, in addition to these two major vectors, *An annularis* is responsible for local transmission. *An. sundaicus* is responsible vector for malaria transmission in coastal regions of Rakhine, Mon and Taninthayi Region [8,35,29,14]. *An. dirus* and *An. minimus* are also main vector of malaria in Thailand [21,22]. *Anopheles culicifacies* and *An. stephensi* are main vector of malaria in India [7,36]. In Indonesia there are 24 *Anopheles* species recorded throughout the country [37,38,39]. The most extensively occurring species of Anopheline mosquitoes in Indonesia are *An. sundaicus, An. subpictus, An. barbirostris, An. maculatus, An. aconitus,* and *An. bablabacensis* and all are implicated in malaria transmission [38,40].

The breeding sources of *Anopheles* larvae in Katinehtit village was found 8 kinds of water sources as water pools, rock pools, sand pools, Rice fields, Ponds, slowing running water, water bed of Yunsalin creek and foot prints. Of these the highest density of *Anopheles* mosquitoes were collected from rice fields followed by sand pools and lowest density of *Anopheles* mosquitoes were collected from slowing running water. Main vector *An. dirus* and *An.*

minimus larvae were collected from Rock pools and *An. minimus* larvae were collected from water pools, Sand pools, slowly running water and bed of Younsalin creek and found together with secondary vectors of *An. maculatus, An. aconitus , An. culicifacies* and *An. philippinensis* and other non-vector of *Anopheles vagus, An. barbirostri*s and *An. hyrcanus* larvae. Other researchers observed that *An. dirus* larvae were collected from rock pools and *An. minimus* larvae were abundantly collected together with *An. culicifacies* larvae in sand pools in Thabweywa village in Oktwin Township Bago Region and abundantly collected from domestic water wells, in Mon State and Ye Phyu Township Taninthayi Region and the density of both main vector larvae were slightly lower than the previous study in same area of Kamamaung Township Kayin State [9,14,12]. In Kenyan, only two productive larval habitats for *An. gambiae* and *An. funestus* Giles were available along the Jaribuni River and in Mtepeni. These habitats were swampy areas that never dried up after the previous rainy season [31].

The vector density fluctuates with annual rainfall patterns. In some areas, vector breeding sites may be flushed out with rainfall during the monsoons with higher density being reported in post monsoon. The peak transmission season in Myanmar generally lies between March and December [8,9,14,12,29]. The planning of future malaria vector control interventions requires information on the vector population, such as vector dispersal and survival. This information is important not only as determinants of the epidemiology of malaria but also for operational malaria vector control activities [41]. The dispersal of mosquito vectors to find mates, nectar sources, resting sites, ovipositional sites, and blood meals-underlies the spatial distribution of vectors, and it plays a major role in shaping population structure [42].

Mosquito survivorship is an important factor that determines vectorial capacity and malaria transmission potential [43]. Feeding on different sources of natural plant-derived sugars can influence key traits that affect the capacity of mosquitoes to transmit malaria, including mosquito longevity and mosquito susceptibility to *P. falciparum*. When combined into an epidemiological model these effects have important consequences for malaria transmission [44]. Gu et al., [45] reported that the probability of mosquito survival over the extrinsic incubation (10 days) was ca. 0.04 in the sugar-poor site, as compared to 0.48 in the sugar-rich site. It is well documented that the effects of interventions on the mosquito survival rates are extremely important [46].

In the natural condition, the survivability rate of *An. dirus, An. minimus, An. aconitus, An. philippinensis, An. vagus* and *An. culicifacies* were kept under the banana plants groups in large paper cups were found *An. dirus* and *An. vagus* were the longest survivability rate for 8 days followed by *An. minimus, An. culicifacies, An. philippinensis* were found 7days and *An. aconitus* was found 6 days of survivability and 100% survivability was found for 4 days in paper cups in natural condition. No eggs were laid by main and secondary vectors during the test although *An. vagus* was found laid their eggs in ovipositional beaker after four days of test. Although in Kenyan study revealed that the survivability of *Anopheles gambiae* and *Anopheles funestus* were found, the daily survival probability was 0.96 for *An. funestus* and 0.95 for *An. gambiae* in Jaribuni and 0.83 and 0.95, respectively, in Mtepeni. The maximum flight distance recorded was 661 m. The high survival probability of *An. gambiae* for 25 days and *An. funestus* for 19 days were estimated accounts for the continuous transmission of malaria along the Kenyan coast in natural condition [31]. Same survivability rate of *An. gambiae* was found in a Nigeria study and mention that the life expectancy of adult mosquitoes was 8.0 and 5.9 days during wet and dry seasons and was significantly different

($p<0.05$). During wet season the mosquitoes survive long enough to become infectious than during dry season. The vectorial capacities was higher significantly in wet season 1.98 than that of the dry season 0.09 ($p<0.05$) [47]. The *An. gambiae* population in Bali district was dominantly old ones due to high rates of daily survival. The longevity of the mosquito makes for high vectorial potential [48].

All the tested *Anopheles* mosquitoes were survived 100% for 4days except *An. philippinensis* for 3days. Then the survivability rate was gradually declined till death for 7 to 9 days in natural condition. It may be due to the fact that *Anopheles* mosquitoes can survive long life when they live unconfined in natural condition. Other researcher revealed that in West Timor the average life expectancy of *Anopheles* spp. ranged from 13 to 20 days [30,49] noted that the average duration life of female *Anopheles* in tropical areas is about 10–14 days and occasionally can reach 21 days [49]. Sandosham and Thomas also observed that the average life span of *An. barbirostris* under laboratory condition can reach 34 days [50] The estimated mean survival time of female *An. gambiae* s.l. in the irrigated and non-irrigated areas of sugarcane plantation scheme in Ethiopia was 37.9 and 31.3 days, respectively. A survival analysis showed that adult females of *An. gambiae* s.l. placed in an irrigated area lived significantly longer than those in a non-irrigated area ($\chi2 = 18.3$, df = 1, $P < 0.001$) [51]. *Anopheles* mosquito needs to survive beyond the extrinsic incubation period of the *Plasmodium* parasites to be able to transmit malaria, the longer a mosquito lives, the higher the number of bites it may inflict [52].

Ndoen and his associates mentioned in their research, of the three species with sufficient longevity for pathogen development, *An. barbirostris* was found inside dwellings and had peak activity during the night. This species thus poses a significant malaria risk during times when people are indoors and asleep. Therefore *An. subpictus*, *An. vagus*, and *An. barbirostris* in west Timor are potential vector of malaria.in Central Java. Bednets and indoor residual spraying would be a worthwhile strategy to control this mosquito species to reduce malaria risk [30]. In Central Java the life expectancy of the two *Anopheles* species was less than 4 days. This is in line with a recent study by Susanna [53] also in Central Java, who found a life span of 3.19 days for *An. aconitus* and 3.27 days for *An. barbirostris.* Since the parasite needs time to develop in a mosquito (8–35 days), the longer the mosquito life span, the more effective the mosquito becomes as a vector [54]. In addition, Warrell and Gilles noted that high-parous-rate mosquitoes are more common in drier areas or in dry season conditions [55]. It may be contributed to the long life survivability of main vectors *An. dirus*, *An. minimus* and secondary vectors *An. aconitus*, *An. philippinensis*, *An. vagus* and *An. cilicifacies* in the study areas. This weather condition might contribute to the longer life span and would be more harmful and have more potential vector to transmit malaria parasite than the other secondary vectors of the *Anopheles* mosquitoes in Katinehtit village. Mosquito survivorship and development may be affected by environmental factors. Temperature (both water and ambient), relative humidity, rainfall, and nutrient availability are key environmental factors governing the dynamics of malaria vectors including development and survival. These factors can be strongly influenced by variation in land use and land cover change such as the vegetation cover, landscape, and distance to water bodies [51].

In the present study, all the collected *Anopheles* mosquitoes were found susceptible to tested Deltamethrin 0.05% Permethrin 0.75% and Cyfuthrin 0.15% insecticides impregnated papers in WHO test kits. Although *An. barbirostris* and *An. hyrcanus* were found 30 to 40 minutes' tolerance to Permethrin, Deltamethrin and Cyfuthrin

insecticides. Same result has been found in Mon State and different parts of Myanmar [56,29]. And also *Anopheles* mosquitoes from Shan, Bago, Mon, Sagaing, Mandalay, Kayin, Magway were susceptible to WHO recommended insecticides impregnated Test kits [24]. Although other researchers revealed that main vector of *An. dirus* and *An. minimus* in Thailand [57], *An. dirus* and *An. minimus, An. culicifacies, An. stephensii* and *An. fluviatellis* in India were resistance to Deltamethin 0.05%, and Permethrin0.75% [36]. *Anopheles gambia* has been shown to be resistant to pyrethroid insecticides in sub Saharan Africa [58].

Anopheles funestus was found resistant to pyrethroid insecticides in South Africa [59]. Pyrethroid resistance has been spreading rapidly in sub-Saharan Africa and has been documented in 23 countries [60]. This may partly be in response to agricultural application and run-off of insecticides into mosquito breeding sites, but increasingly in response to selection pressure resulting from the scale up of insecticide-treated nets and indoor residual spraying as malaria prevention tools. Previous studies in Bungoma and Gem have shown high resistance to pyrethroids in *An. gambiae* in both areas. The species composition of these areas differs. *Anopheles gambiae* comprises >70% of the *An. gambiae* s.l. mosquitoes collected from houses in Bungoma, whereas *An. arabiensis* accounted for up to 90% of the *An. gambiae* s.l. in Gem and surrounding areas [58,61]. Daibin and his party revealed that *An. barbirostris* has developed knockdown resistant to Deltamethrin 0.05% in Bunmout Township Saggaing Region in Myanmar although *An. barbirostris* are vector of malaria in Indonesia [62,53].

5. Conclusion

Malaria is endemic in some region in Myanmar where very hard to reached by vehicle and border areas where are insurgent areas. COVID-19 pandemic and different crisis in all areas in Myanmar where malaria is endemic and malaria control measure is restricted. The study was conducted in KatineHtit village Kamamaung Township, Kayin State to know vector bionomics and survivability of mosquito population. A total of 2207 mosquitoes consisted of 13 Anopheline species were collected. Moderate number of main vector *An. dirus* and high density of *An. minimus* were collected in the village. The highest density of *An. hyrcanus* and *An. philippinensis* were collected followed by *An. barbirostris, An. culicifacies* and *An. minimus* and lowest density of *An. varuna, Annularis* and *An. jamesii* were collected. High density of main vectors *An. dirus* larvae were collected from rock pools and *An. minimus* were collected in high density from sand pools and rice fields, secondary vectors were collected from water pools, sand pools, creeks, slowly running water and *An. vagus* were collected from foot prints. The survivability rate of tested *Anopheles* mosquitoes was found 7 to 8 days and survivability rate was found gradually decline within 8 days. The susceptibility of WHO recommended insecticides as Deltamethrin 0.05%, Permethrin 0.75% and Cyfuthrin 0.15%. The above information's are very important and very usable information for controlling potential vectors in community. And should be destroyed all larval habitats to control transmission of malaria via to reduce vector *Anopheles* and should be distribute LLINs nets to prevent mosquito bite. And, should be searched additional potential vector in this malaria endemic area.

Declarations

Source of Funding

This study has not received any funds from any organization.

Conflict of Interest

The authors declare that they have no conflict of interest.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contribution

All the authors took part in data collection, literature review, analysis, and manuscript writing.

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